April 1990

DCIEM No. 90-TR-23

(2)

THERMAL ASSESSMENT OF MUSTANG INDUSTRIES INC. NEOPRENE QUICK-DON ANTI-EXPOSURE IMMERSION SUITS AND STORAGE EVALUATION FOR THE CP140 AURORA AIRCRAFT

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ABSTRACT

As reported in DCIEM Report No. 89-TR-09, "Development of a Canadian Forces Quick-Don Anti-Exposure Immersion Suit", Mustang Industries Ltd. developed a 3mm neoprene quick-don immersion suit to replace the quick-don anti-exposure flying coverall currently in use in the Canadian Forces (CF). It was known that the 3mm suit could not be stored in all 18 stowage positions in the CP140 aircraft; however, it was noted that the Aurora has sufficient spare storage space that stowage should not be a problem. Subsequently, DCIEM/MLSD was tasked to assess the thermal protection offered by 1mm and 2mm suits, compared to the 3mm suit, and to find suitable stowage locations in the CP140. It was found that the 1mm, 2mm and 3mm Mustang suits all provide considerably more thermal protection than the CF quick-don suit. Also, these three suits can be stored in the CP140 if appropriate modification or relocation of some stowage positions are made.

TABLE OF CONTENTS

STOWAGE ASSESSMENT

There are a total of eighteen quick-don immersion suits carried aboard the CP140 aircraft (Table 1). Port-side and starboard-side stowage locations are indicated in Figures 1 and 2 respectively. There are three methods used to secure the suits as follows:

a. vinyl bags (Fig 3) - at the three flight-deck locations;

b. fixed-dimension storage bins - four pigeon holes (17 cm diameter x 39 cm length) (Fig 5) at the NASO and ASO locations holding one suit each and one triangular bin (left side 43.2 cm, bottom 20.2 cm plus 17.7 cm sloping slightly upward, hypotenuse 50.8 cm) on the fore end of the search stores rack holding three suits; and

c. adjustable tie-down straps (Fig 4, 6, 7) - at the other eight locations.

The 1mm Mustang suit fits into all 18 positions on the aircraft.

The 2mm and 3mm suits are bulkier than the 1mm suit and do not fit into all the current stowage locations. In an effort to decrease the size of these suits, vacuum packing was tried. Unfortunately, vacuum packing does not significantly decrease the volume of the packed suit because the closed-cell neoprene material does not compress. When vacuum packed, the suits are hard and rigid and not as easily handled into and out of some of the stowage sites, i.e. the flight deck bags. Also, a vacuum packed suit requires more time to prepare for donning.

The 2mm and 3mm suits can be stored at the tie-down strap locations (Fig 4, 6, 7); however, because of their bulk, they will not fit into:

a. the vinyl bags at the three Flight Deck positions (Table 1 - Suits 1, 2, 3) (Figure 3);

b. the four pigeon holes (Table 1 - Suits 5, 6, 10, 11) (Figure 5);

c. the triangular bin (2 Mustang 2mm or 3mm suits vice 3 CF suits) (Table 1 - Suits 12, 13, 14).

It should be a relatively minor modification to increase the size of the Flight Deck bags (Fig 3) to accommodate the 2mm and 3mm suits. Because of the limited space available where the Pilot's suit (Suit 1) is stowed, the 3mm suit will have to be moved and co-located with the Flight Engineer's (Suit 3) (Fig 3). Additional stowage positions will be required to store the four suits from the pigeon holes and the one suit from the triangular bin. The following alternative stowage positions have been identified:

a. port aircraft wall ahead of NAVCOM station (Suit 7) (relocate Suits 5 & 6 to Suit 7 position - modify tie-down strap to hold suits in vertical vice horizontal position);

b. port aircraft wall aft of TACNAV station (Suits 8 and 9) (Fig 6) (relocate Suit 10 to Suite 8 and 9 position - modify tie-down straps to hold suits in vertical vice horizontal position);

c. the top shelf of the sonobuoy search stores rack above the parachutes (Figure 8) (not currently used) (relocate Suits 11 and 14). This might require packing the 2mm & 3mm immersion suits in a lower-profile folded configuration rather than the normal rolled-up shape;

d. the broom closet at rack H (Fig 1) (currently used but space available for suits);

e. the two dinette seat bins (Fig 9, 10) (currently used but space available for suits); and

f. the lower cupboards of the maintenance station (Fig 2) (currently used but space available for suits).

The Aurora crew do not approve of the locations indicated at d, e and f above; they prefer to have their suits located near their workstations so they do not cross each others' paths during preparation for ditching. Therefore, they prefer the stowage options indicated at a, b and c above.

Enlarging the flight-deck storage bags and utilizing the stowage options indicated at a, b and c above are recommended as the best solutions to the problem of storing the 2mm and 3mm suits on the Aurora aircraft.

THERMAL PROTECTION ASSESSMENT

CORD Group conducted thermal insulation tests in calm and turbulent water on CF and Mustang quick-don immersion suits utilizing their Thermal Instrumented Mannikin (TIM) (3, 6).

The suits tested were:

a. CF Quick-Don Immersion Suit;
b. Mustang Quick-Don Immersion Suit (1mm neoprene)(Type III);
c. Mustang Quick-Don Immersion Suit (2mm neoprene)(Type III);
d. Mustang Quick-Don Immersion Suit (3mm neoprene)(Type III); and
e. Mustang Quick-Don Immersion Suit (3mm neoprene)(Type I).

The Type I and Type III suits are of similar construction except that the seams are taped and glued on the Type III suit providing improved leak protection.

Testing the Type I suit with its leaky seams provided useful data by demonstrating the insulation value of the closed-cell polychloroprene (neoprene) material should the immersion suit leak allowing considerable water to enter the suit and wet the garments worn underneath. During the CORD tests, the 3mm Type I suit had severe leakage with all underclothing saturated except the chest area (6). As can be seen in Table 2, the anticipated calm water survival time for the leaky Type I suit is not significantly less than for the Type III suit which leaked very little. Because of the thermal protection provided by the neoprene material of the Mustang suits, leakage does not have a catastrophic effect on the anticipated immersed survival time (Table 2); however, the extra protection and comfort might be worth the effort required to test and repair the suits at acceptance and periodic inspections.

Using the clo values determined by the CORD Group (3,6) and the anticipated survival time chart (Figure 11) included in the ASCC AIR STD 61/40A (7), it is possible to predict the anticipated survival times for individuals immersed in cold water wearing dual-layer summer flying clothing and the different types of quick-don immersion suits evaluated for this project (Table 2). When deciding which suit to choose the survival time requirement based on local SAR times should be considered (7).

When using Table 2, one must keep in mind that the chart was derived empirically by mathematical modelling and conservatively applied to the 10th percentile individual. With the complexity of factors involved, it is noted that there is no guarantee as to the accuracy of the predicted survival time on an individual case basis.

What the information displayed in Table 2 does show is that the Mustang Quick-Don Immersion Suits provide much better protection from immersion hypothermia than the current CF Quick-Don suit. Also, the relatively similar results achieved with the 3mm Type III suit which had minimal leakage and the 3mm Type I suit which had severe leakage shows that the Mustang Neoprene Quick-Don Immersion Suit continues to provide good thermal protection even when undergarments are soaked.

As noted in the CORD report (6), all suits tested leaked. The CF Quick-Don Immersion Suit had the least leakage of all, occurring only in the left arm. The 1mm suit leaked the least of the Mustang suits with only the back of the left leg and top and back of the right leg dampened. The 2mm suit had the next greatest amount of leakage wetting all the clothing on the back, buttocks and legs. The worst leakage was in the 3mm Type I suit as described above. In an earlier test at DCIEM, the 3mm Type III suit did not leak (4).

To quantify the leakage described above, in October 1989 Mustang and DCIEM personnel performed water-tight integrity tests IAW RAF/IAM/478 (8) on the three Mustang Type III suits. The Type I suit was not included because of its inferior seam construction. The amounts leaked are shown in Table 3. The 675 ml leakage in the 2mm suit was caused by a puncture in the suit material and was much greater than the amount leaked through construction points on the 1mm and 3mm suits (< 25 ml and 1 ml respectively).

Because the water-tight integrity test (8) is done with the suit turned inside out and filled with approximately 150 litres of water, the material stretches. Therefore, it was felt that perhaps the leakages were greater than would be experienced when the suits are worn by human subjects and immersed in water. To test this theory the three Type III suits were worn by Mustang and DCIEM personnel in a swimming pool. The immersion suits were worn over turtleneck, long summer-weight underwear, and grey wool socks; these garments would show the areas of leaks. After the immersion suits were donned, the personnel jumped into the pool from the side, released the air trapped inside the suits and swam, paddled, floated or maintained a vertical position for a total of 20 minutes. Then the immersion suits were doffed, undergarments were checked for wetness, subjects and the inside of the suits were towelled, and the undergarments and towels were weighed to determine the amount of leakage (Table 3).

The leakages recorded in the pool tests for the 1mm and 3mm suits were considerably greater than expected - disproving the stretched-material theory discussed above - and demonstrate the need for the manufacturer to perform pool testing to ensure their watertight integrity.

It should be noted that little leakage occurred at seams or other construction points on the Type III suits. Most of the leakage occurred at what appeared to be punctures in the material; these punctures might have occurred during handling and/or shipping. The fact that all the Mustang suits leaked to some degree suggests that acceptance tests and periodic inspections will be necessary. At the acceptance testing, any leak points should be repaired when they are first found; rather than testing to determine the amount of leakage, acceptance testing should be performed to ensure that the suit is water-tight to the standard indicated in RAF/IAM/478 (8).

CONCLUSIONS

The Mustang 1mm Type III Quick-Don Immersion Suit will fit into all 18 storage positions on the CP140. If it is decided that the greater thermal protection provided by the 2mm or 3mm suit is desired, appropriate storage facilities can be made available by enlarging the flight-deck bags, moving the Pilot's suit, and relocating five suits currently stored in the pigeon holes (4 suits) and the triangular bin (1 of 3 suits).

The three Mustang Type III Quick-Don Immersion Suits (1mm, 2mm, 3mm) all provide considerably more thermal protection than the Quick-Don Anti-Exposure Flying Coverall currently in use in the CF. In 0^{o}C calm water, the 1mm, 2mm and 3mm suits provide projected survival times (Table 2) of 3.3, 4.1 and 6.5 hours respectively, compared to 1.6 hours for the current CF Quick-Don suit. When deciding whether to select the 1mm, 2mm, or 3mm suit, SAR times should be considered as indicated in ASCC Air Standard 61/40A (7).

Acceptance and periodic inspections in accordance with RAF/IAM/478 (8) of all suits should be performed to ensure suits in service leak as little as possible and therefore provide maximum thermal protection. The anticipated survival time in cold water (Table 2) is degraded if the suit should leak; for example, the anticipated immersed survival times in 0^{o}C calm water for the 3mm suit degrade from 6.5 hours with minimal leakage to 5.2 hours with severe leakage.

RECOMMENDATIONS

When criteria are established for a reasonable insulative standard for immersion suits, taking into consideration SAR times, the appropriate Mustang Quick-Don Immersion Suit that satisfies those requirements should be selected to replace the current CF Quick-Don Immersion Suit.

Suitable CP140 storage facilities are available for the three Mustang suits (1mm, 2mm, and 3mm) and need not be a determining factor in the final selection decision.

Appropriate acceptance and periodic inspections and repairs should be implemented to ensure the suits' optimal performance.

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7. **Air Standardization Coordinating Committee, Air Standard 61/40A;** Technical Basis for Specifying the Insulation of Immersion Protection Clothing; May 1989.

8. **RAF/IAM/478;** A Simple Test of the Watertight Integrity of Immersion Suits; December 1982.

Table 1. Stowage Positions of CP140 Quick-Don Immersion Suits

Ditching Position	Suit Number	Suit Location
Pilot	1	Front of Rack 1
Co-Pilot	2	Front of FELC
Flight Engineer	3	Bulkhead above Rack 1
Forward Observer	4	Front of Lavatory Wall
NASO-1 and NASO-2	5, 6	Above back of NASO-1 console (Pigeon Holes)
NAVCOM	7	Port aircraft wall ahead of NAVCOM station
TACNAV and ASO-2	8, 9	Port aircraft wall aft of TACNAV station
ASO-1 and Search Rack (floor ditching station)	10, 11	Above rear of ASO-1 console (Pigeon Holes)
Port overwing floor ditching stations	12, 13, 14	Above sonobuoy tubes 7 and 8 against port aircraft wall (Triangular Bin)
Port Observer	15	Bulkhead aft of Port Observer
Starboard Observer	16	Bulkhead aft of Starboard Observer
Galley	17	In parachute stowage area above Rack J
Galley	18	In parachute stowage area above forward galley closet

Table 2. Anticipated Survival Time (hrs)

		clo* Value		0°C		5C		10°C	
Suit	Leakage	CW	TW	CW	TW	CW	TW	CW	TW
CF Quick-Don	minor	0.3636	0.2647	1.6	1.4	2	1.9	3	2.8
1mm Type III	moderate	0.5654	0.5404	3.3	3.1	5	4.6	9	8.7
2mm Type III	moderate	0.6115	0.4892	4.1	2.4	6	3.7	10	7.6
3mm Type III	minimal	0.7703	**	6.5	**	9	**	> 12	**
3mm Type I	severe	0.6887	0.4934	5.2	2.5	8	3.8	11	7.7

* 1 clo + 0.155°Cm^2/w
** = not available
CW = Calm Water
TW = Turbulent Water

Table 3. Leak Data for Mustang Type III Immersion Suits

	Leakage (ml)	
Suit Thickness	Integrity Test	Pool Test
1mm	< 25	296
2mm	675	360
3mm	1	229

Figure 1. Port-Side Stowage Locations of Fifteen Immersion Suits on CP140

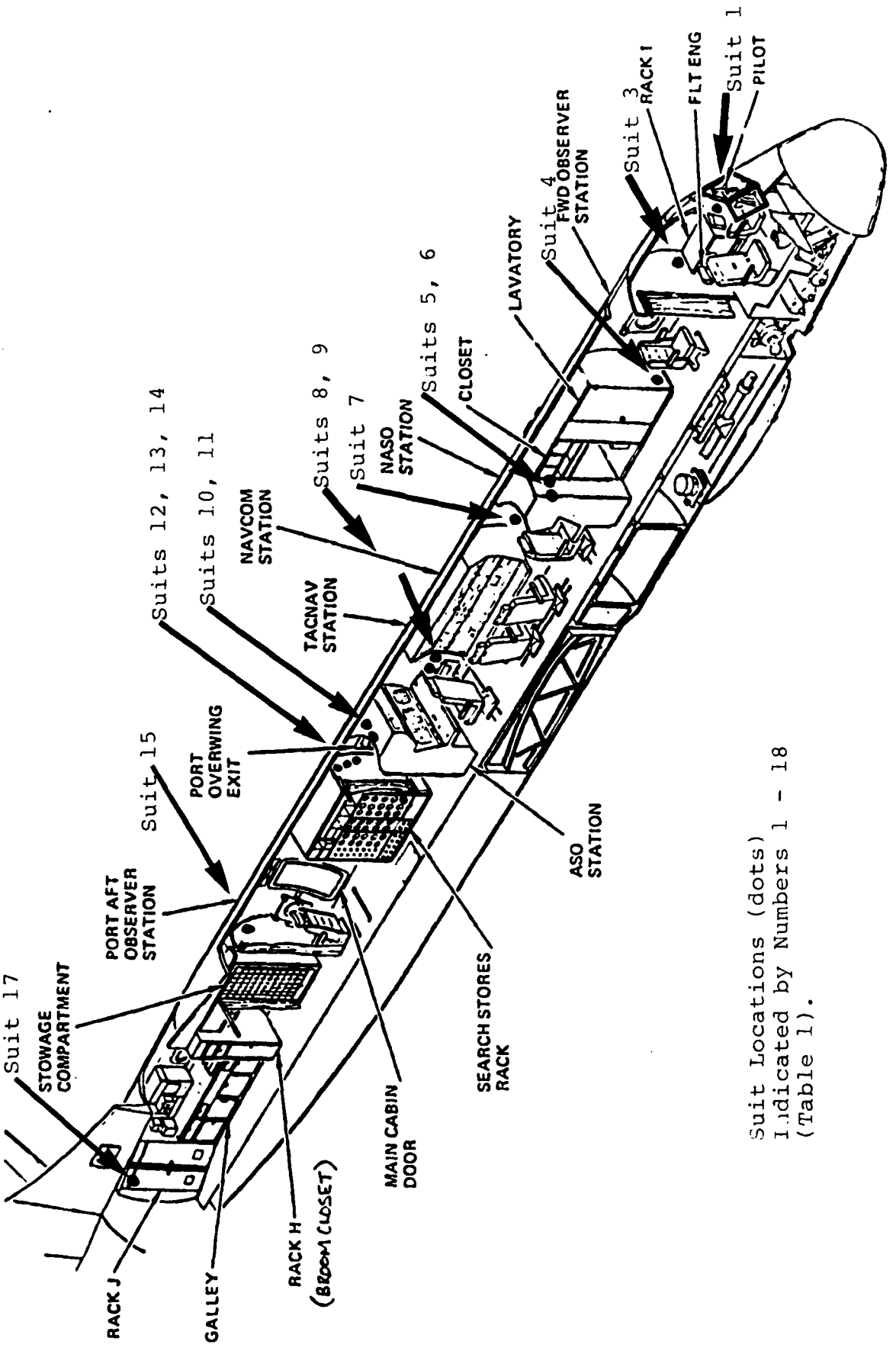


Figure 2. Starboard-Side Stowage Locations of Three Immersion Suits on CP140

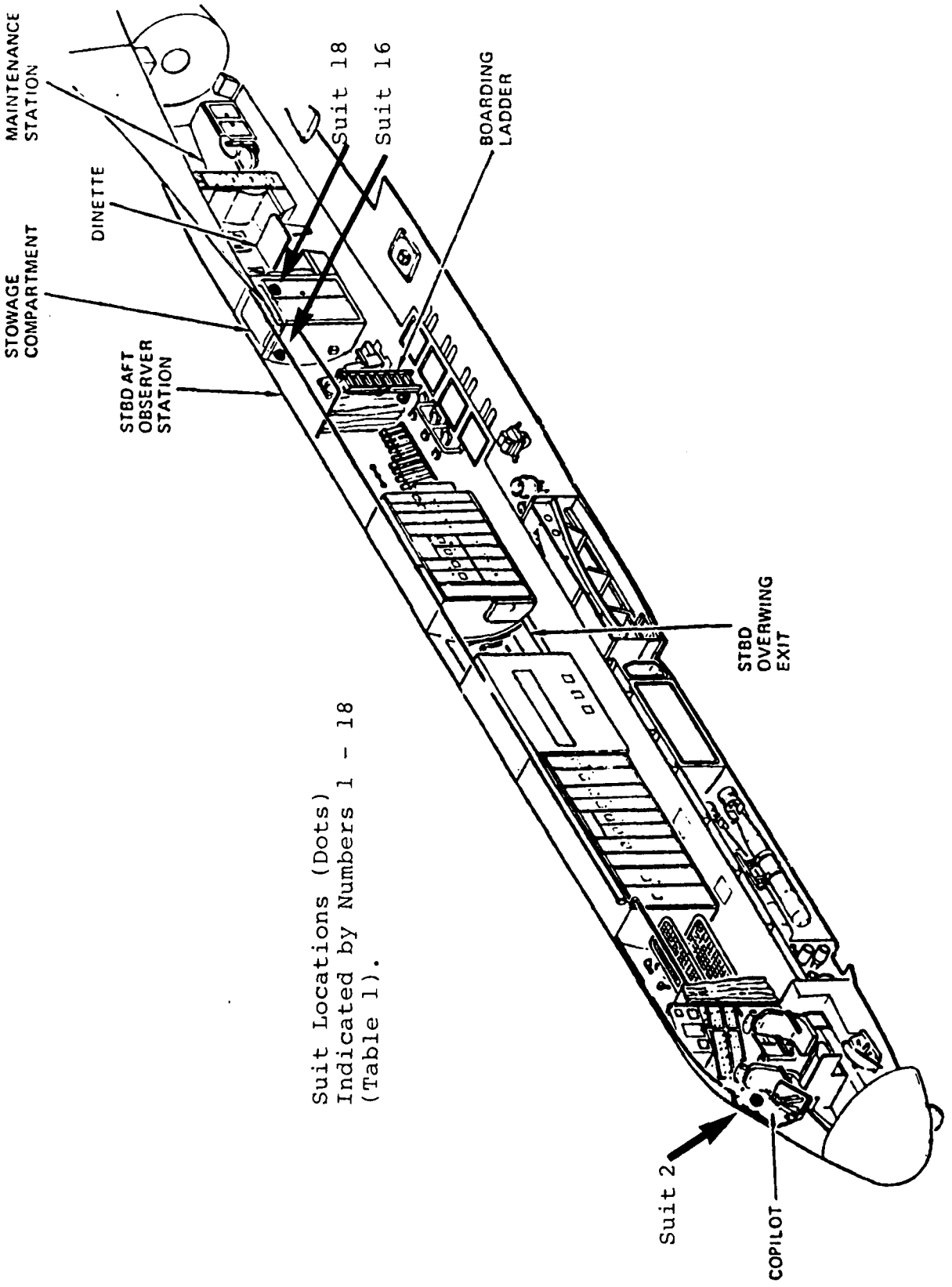


Figure 3. Flight Deck Stowage Position - Suit 3

The CF Quick-Don Suit in position
on Bulkhead above Rack 1 behind the Pilot's seat.
The stowage bags would require enlargement
to carry the Mustang 2mm or 3mm suit.

Figure 4. Fore Observer Station - Suit 4
CF Quick-Don Suit in-situ
on front wall of lavatory

Figure 5. Above Back of NASO-1 Console - Suits 5 & 6

The 1mm suit is shown stowed in the left hole, with the current suit on the right. Two more pigeon holes are in the port overwing exit area aft of the ASO Station.

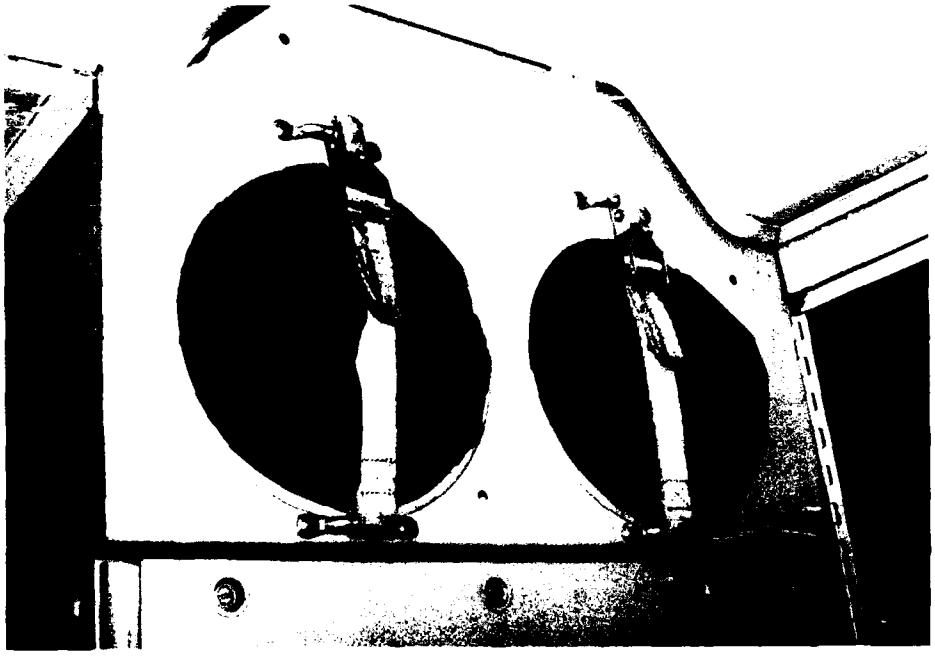


Figure 6. TACNAV and ASO-2 Station
Suits 8 & 9

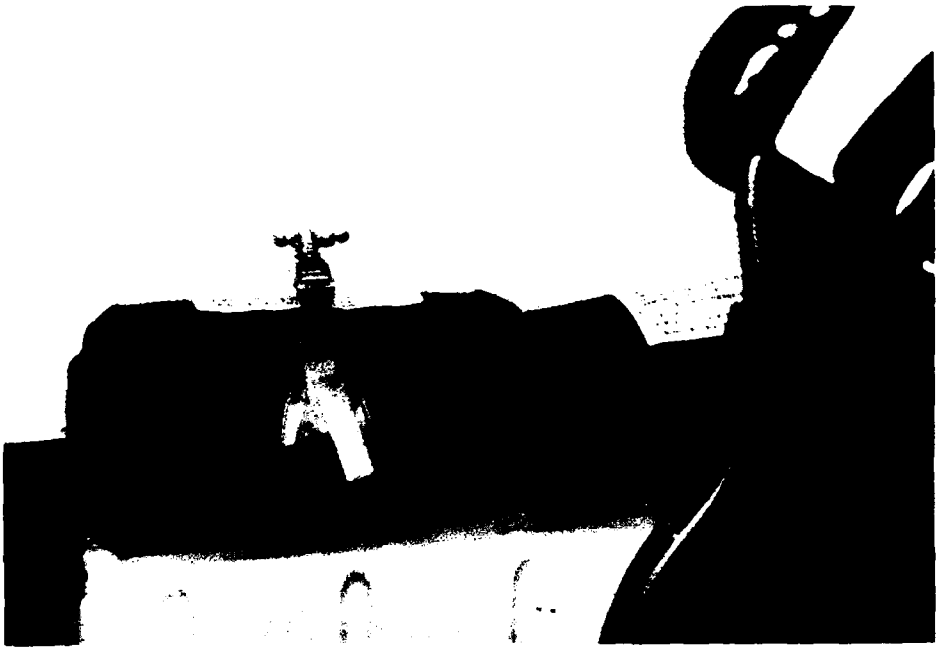


Figure 7. Port Aft Observer Station - Suit 15
CF Quick-Don Suit in-situ.

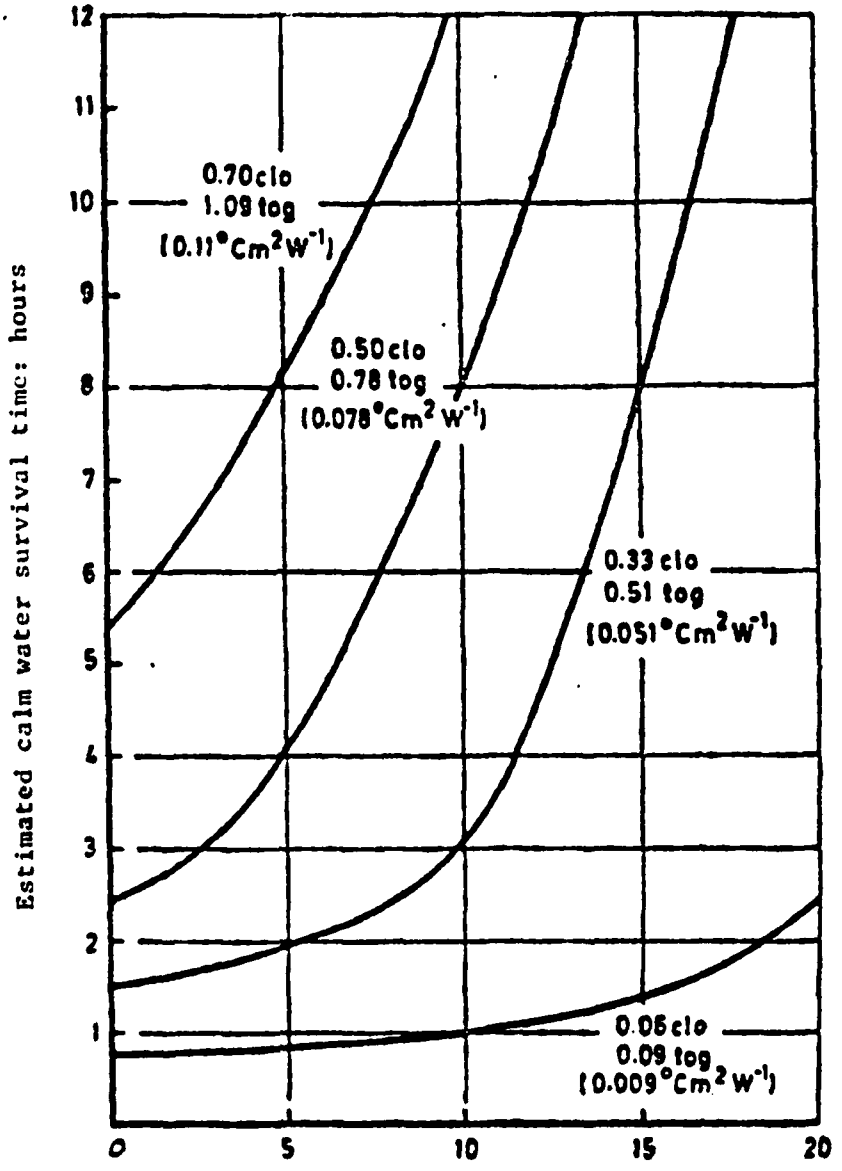
Figure 8. Top Shelf of the Search Stores Rack.
This space could be used to store immersion suits in low-profile folded configuration.

Figure 9. Dinette Area.
Seat cushions may be lifted to gain access to storage bins.

Figure 10. Dinette Area.

Seat lifted to show storage bin that could be utilized for immersion suit stowage.

Figure 11. Predicted Survival Time Against Sea Temperature
For Thin Persons (10th percentile mean skinfold thickness)
And For Four Levels of Immersed Clothing Insulation
In Calm Water Conditions (from Air Std 61/40A (7))



- The four graphic lines represent the overall insulation measured in water under conditions representative of an actual survivor supported in a life preserver.
- 0.06 clo represents light-weight clothing without an immersion suit.
- 0.70 clo represents an effective immersion dry suit worn over a pile fabric insulating undergarment.

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Ferguson, Donald W. - Captain
Sturgeon, Wayne R. - Captain

5. DATE OF PUBLICATION (month and year of publication of document)

April 1990

6a. NO. OF PAGES (total containing information. Include Annexes, Appendices, etc.)

18

6b. NO. OF REFS (total cited in document)

8

6. DESCRIPTIVE NOTES (the category of the document, e.g. technical report, technical note or memorandum. If appropriate, enter the type of report, e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.)

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9a. PROJECT OR GRANT NO. (if appropriate, the applicable research and development project or grant number under which the document was written. Please specify whether project or grant)

3752A-T51CB-55T/DAS Eng 40

9b. CONTRACT NO. (if appropriate, the applicable number under which the document was written)

10a. ORIGINATOR'S DOCUMENT NUMBER (the official document number by which the document is identified by the originating activity. This number must be unique to this document.)

DCIEM No. 90-TR-23

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Immersion Suit - Quick-Don
Thermal Protection - in cold water
Neoprene Anti-Exposure Suit
Quick-Don Suits - Stowage in CP140 (Aurora)

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